ON WHAT CONSTITUTES A CONSTRUCTIVE ARCH IN ARCHITECTURE.*

I was led to put these observations together from some remarks in a paper by Mr. Edmeston,† wherein, while suggesting how an architect should construct an iron church, if he were called upon to do so, he makes these observations—"But the thought of piers and arches to divide his nave from his aisles occurs to" the architect: "no, so far as the arches at least, he rejects that at once." And further he says,—"that the arch, the principles of which are the tendency of wedge-like *voussoirs* to bear towards a common centre, can have no place under the circumstances with which he has to deal."

I suggested at the time that, on the contrary, the arch could be applied to great advantage in such a structure; and that I considered *the arch to be the best and safest principle upon which to use cast iron*; and I instanced Southwark-bridge as a large and fine example of the application of the iron arch. Mr. Edmeston was of opinion that this was not an arch at all,—or at least that it was not upon the same principle as a stone arch, which consisted of a series of wedge-like stones called voussoirs. The same opinion, in different forms, was expressed by other members who spoke at the time; and it appeared to be pretty generally considered that if a cast-iron arch consisted of one or only a few parts, it was not then upon the principle of the arch as usually constructed in stone. I however consider such opinions to be entirely erroneous, and that the principle of the arch is precisely the same in stone and in iron, whether it be made with or without voussoirs. I will, therefore, to the best of my ability, endeavour to elucidate the principle upon which arches are usually constructed.

An arch, then, may consist of one piece as well as a hundred: it is not the joints which form an arch or the wedge-like form of the voussoirs. These alter according to the nature of the material of which the arch is to be constructed.

The principle of an arch is that of a bow, or a bent piece of wood, the abutments or supports of which are at right angles to the curve; or the feet are tied together by a tension rod or other means. Every particle of the bow, be it of wood, stone, or iron, must be in a state of compression, all tending in the direction of the curve towards the abutments: the abutments must, therefore, be at right angles to such curve. This must also be the case with every transverse joint in the arch: it must be at right angles to the curve,—that is, in the direction of the centre; and if each joint be looked at in the light of an abutment, which it really is, instead of looking at the material itself in the shape of a voussoir the principle will appear clearer. Every transverse joint acts in the manner of an abutment to carry the pressure from the crown towards the extreme abutments at the foot of the arch. Now it must be evident that if from the nature of the material used it can with propriety be made all in one piece, the pressure is carried to the abutments precisely in the same manner by the material itself, but without any transverse or butting joints. If on the contrary, in the case of an iron girder, for instance, the lower side of which consists of a segment of a circle, the supports are horizontal instead of being at right angles to the curve, we lose the principle—we have only the arch form,—but, put the abutments at the proper angle to resist pressure, and we immediately get a true arch. Every particle of the metal is in compression. In different materials the *manner* of constructing an arch may be different, but the *principle* is the same in all. Before the principle was known as in an example found at Mycenæ, called the treasury of Atreus, the courses were laid horizontally, each projecting beyond the others, with the lower angles cut away to the form of an arch. Here we lose the principle: the joints are not at right angles to the pressure. Voussoirs, properly so called, are perhaps only used in stone arches, but to show that arches may be constructed without voussoirs, I will instance a few examples. Arches may be successfully turned with three or four courses of plain tiles laid in cement, the joints of each course alternating with those below. In a somewhat similar manner arches may be formed with several thicknesses of timber bent to the curve, the butting joints of the timbers alternating with each other, and the whole bolted together at intervals. The semi-circular ribs of the transept roof of the Exhibition building, 72 feet span, were formed upon this principle by three thicknesses of timber, and external and internal rings of wrought-iron, the whole bolted together at intervals. Ribs of the same kind are also used at the King's Cross station of the Great Northern Railway, and consists of sixteen thicknesses of 1½ inch each. Another mode of forming wooden arched ribs is to place the wood side by side, and consist of two or more thicknesses, which are cut to the curve in lengths not so great as to weaken the timber, and securing these well together by bolts or keys, and observing especially to break the joints of the several thicknesses. This method is said to be the invention of Delorme, about the year 1561, and was applied to the formation of domes.

Palladio has given a design for a timber bridge, which, in the words of Gwilt, "is remarkable as having been the earliest that has come to our knowledge wherein the arrangement is in what may be called framed voussoirs, like the arch stones of a bridge, a principle in later days carried out to a great extent, and with success, in iron as well as timber bridges."

Bows, or bent pieces of wood, are sometimes applied to stiffen ordinary beams, and form a very simple manner of increasing their strength.

Cast iron arches have been used to a very great extent in roofs and bridges, and are often of a very light and elegant character. They appear, from the illustrations given of them in THE BUILDER,* to have a very excellent effect in the roof of the Diana Baths at Vienna. A roof of a similar character was put up to form a new sorting room at the Post-office, by Mr. Sydney Smirke.† This is an excellent example and possesses some peculiar features. It was erected without disturbing the ceilings of the rooms below. It consists of a semicircular arch, the feet of which are tied in by horizontal cast-iron girders, which carry the floor, and are suspended by wrought-iron rods, at two points, to the arch above. The arch is in four parts, the external form being that of the roof, which gives an increased depth where it is most wanted—at the haunches. In consequence of so much weight being brought upon the centre of the arch, cross bolts are also added at the haunches, to resist any tendency there might be to give at this point. This is an illustration of the value of metal. All tendency to thrust at the feet is counteracted by the horizontal girders, and instead of weighting the haunches, as would be obliged to be the case with stone, the parts are tied and kept in their places by cross bolts. As to its being upon the same principle as a stone arch, there can, I think, be no doubt: the three joints answer to the joints of voussoirs.

The arch of Southwark-bridge consists of six or eight ribs, placed parallel to each other, and divided into a certain number of equal parts, I do not know how many, and at each joint a transverse plate crosses the whole, and forms a complete iron framework: besides this, there are diagonal ties to prevent racking. This is precisely upon the same principle as the framed ribs in Palladio's wooden bridge.

Southwark-bridge is as large and fine an arch as has yet been erected—but we do not yet know the capabilities of cast-iron in the formation of large arches. I believe it possible to construct an arch that would bear all the weight that bridges are required to bear, and to be a perfectly firm structure, of at least a thousand feet span, or equal to striding the whole width of the river Thames in one arch.* Now this, or any thing like it, could not be attempted in stone, *principally* from the difficulty of preserving its equilibrium.

Some years ago I made working drawings for a bridge upon the same principle as Southwark—but it was only 60 feet span—the centre arch of Southwark is 250 feet—it had six ribs, and each rib was divided into five parts, therefore there were five transverse plates. After this bridge had been executed about six months or thereabouts, one winter night when the mail coach was passing over, it failed. The bolts and flanges burst asunder with a noise resembling a charge of artillery. Engineers were had down to see it (it was in the country): it was examined in every part, but no one could say why it failed. It was thought that the abutments must have given way, for nothing was to be seen the matter with the iron work. However, when it was taken down, previous to putting to rights, it was found that the contractors had cast the ribs too short. They met each other *only at the top*, and the joints were filled up with wooden plugs from below. Instead, therefore, of being supported upon the principle of the arch, that is, one continuous bow from abutment to abutment, the bridge was supported by the flanges and bolts. Now, if the contractors or their men had only known upon what principle they were working, how easily might their mistake have been remedied! A cast-iron voussoir might have been introduced to make up for the deficiency of length in the ribs, and all would have been right. In restoring the bridge the centre portion of each rib was cast a little longer than the others.

In arches of roofs or girders the thrust may be often very advantageously taken by tie bolts, upon the principle of the bow being confined by its string.

In a horizontal beam the upper portion is in compression while the lower is in tension.

In an arch, as I have already said, every particle of the material *must* be in compression.

In an inverted arch, as in the suspension bridge, the action is directly reversed: every portion of the arch is then in a state of tension. Now, as a general rule, wrought-iron should be used when required to be in a state of tension, and cast-iron when in compression.

Wrought-iron is of a fibrous nature, and, consequently, highly cohesive, and as, of course, it will also bear a great amount of compression, it appears very applicable, if it could be easily rolled into the necessary forms, for horizontal girders, in place of cast-iron.

Cast-iron being of a crystalline nature, with minute spaces between the crystals, its cohesive property is low: it should be used, therefore, only in compression, and never, to any great extent, in tension. Now, as the lower portion of a horizontal beam is always in a state of tension, it appears highly desirable that such girders should be either of rolled wrought-iron or upon the principle of the arch. If used quite horizontal, a wrought-iron bar in a groove on the under side, and bolted to flanges at each end, would be an improvement. But to use cast-iron in horizontal beams for long bearings, as is very commonly the case in the present day, trusting to the cohesive quality of the iron, appears to me a very dangerous practice, and is the cause of most of the accidents which occur in the use of this metal.

JAMES K. COLLING.

ISLINGTON.—A correspondent says,—Knowing that your publication has been the means of much improvement to our city and suburbs, I beg to call your attention to the range of some twenty or thirty houses immediately opposite and facing the Angel and Peacock inns in the High-street, Islington. I wish much to see the whole of this worn-out and crumbling block, with the dreadful hovels at the back, raised to the ground, and a neat square of good, but not large, built houses on the site: the contiguity to town would ensure good tenants.

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* Read at the ordinary meeting of the Architectural Association on Friday, Jan. 2.

† See THE BUILDER, p. 781, vol. ix.

* See vol. ix. pp. 138, 186.

† See THE BUILDER, vol. iv., p. 42.

* It was mentioned at the meeting that such a bridge had been proposed by Telford, instead of the present London bridge.

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